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INDUSTRIAL INSIGHTS
ON THE
DOD CONCURRENT ENGINEERING
PROGRAM

Contract MDA972-88-C-0010

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PREFACE

This report was prepared by The Pymatuning Group. However, acknowledgement of the individual contributors to large segments of the report is key to the premise of the Report: namely, that the best insights on an industry activity can only come from the involved industry.

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EXECUTIVE SUMMARY

PURPOSE

This Report presents some first insights from a cross-section of industrial officials asked to consider DoD's newly-initiated Concurrent Engineering Program. Since the implementation of this Program will take place principally in the laboratories of industry and on the production lines of industry, it is industrial managers and officials that must understand, support, and justify the costs of the associated changes to corporate management and corporate Boards.

At the same time, to the Defense Industrial Base, DoD is for all intents and purposes a "monopolistic" customer. DoD acquisition regulations, requirements, schedules, and audits govern the defense marketplace. It is DoD, therefore, that takes the lead in introducing changes that must be implemented by defense vendors as a sort of "entry fee" to the defense market.

[illegible], manufacturing, purchasing, contracts, marketing, combat readiness, economics, industrial base, [illegible]

METHOD OF APPROACH

Meaningful interaction between industry and DoD is always difficult. This is sometimes intentional as prescribed by law, sometimes intentional as directed by DoD, and sometimes unintentional through lack of understanding and difference of purpose.

In this instance, the needed insights by industry on how best to introduce and implement Concurrent Engineering practices were so important to OSD in the formative stage of the program, that The Pymatuning Group was asked to employ a quick-reaction mechanism that would stimulate industry response and expedite its influence on the program. The mechanism employed was that of an Industrial Concurrent Engineering Strategy Forum with voluntary participation by a selected cross-section of industry officials and managers.

CONTEXT - AN HISTORICAL PERSPECTIVE

World War II was a triumph of manufacturing in which the material resources of the United States were marshalled to win a war of attrition. The U. S. won by out-producing the enemy and overwhelming him with its quantity of weapons and logistical support. This emphasis on production was retained by the Department of Defense as a key element of national security strategy until the mid-1950's. Then with the adoption of the "qualitative superiority" policy, manufacturing, the means of production, as a key element of weapons systems acquisition, was implicitly de-emphasized. Coincidentally, and for different reasons, this demphasis of manufacturing in the defense sector was mirrored by a similar change in attitude toward manufacturing in the civil sector.

For the last 20 years, in keeping with the decreased emphasis on manufacturing, both defense and civil sector research in the U. S. has focused primarily on device or product technology to the neglect of process innovation. This single-minded fixation on device technology and performance, has an impact beyond that of slowing manufacturing process innovation: it accentuates the separation between design, manufacturing, and field service. This gives rise to increased problems of producibility and supportability (these issues simply are not considered to any extent in the design phase) and increased development time. As a consequence, we have created very sophisticated weapons systems from advanced device technologies but have been increasingly frustrated by an inability to rapidly and efficiently produce these weapon systems with the reliability and maintainability required to sustain the desired operational advantage. When they are deployed, they suffer from reliability and supportability problems-all traceable to flaws in design and manufacturing.

Many industries in other countries believe that manufacturing is as important as product innovation or marketing in obtaining market share and have increasingly emphasized manufacturing design and process research and development. While it is very difficult to provide precise figures, different studies are in general agreement that Japan spends a much larger fraction of its R&D funds on manufacturing than does the U. S. One study puts the percentage of R&D devoted to manufacturing at 40 percent in Japan versus 10 percent in the U. S. Another study estimates that Japan devotes two-thirds of its R&D funds to improved processes and one-third to improved products, while it estimates that in the U. S. this ratio is exactly reversed. This focus has led to a distinctive competitive advantage and ascension to a position of dominance by foreign manufacturing over domestic industries in key areas.

Industry managers believe that the Defense Industrial Base could produce just as efficiently if modern structural factor changes and manufacturing innovation were emphasized by its primary customer, DoD, rather than continuing with the current emphasis on crippling documentation and on prohibitions to process innovation. If the Defense Industrial Base were allowed to operate effectively industrial leaders believe that the DoD could have all the systems it requires early enough to allow its technical superiority to convey decisive operational advantage, with high reliability so they work when needed, and with corresponding improvement in the "tooth-to-tail" ratio.

There are concerns that the emphasis of engineering education in the U. S. needs to change to an emphasis on integrated interdisciplinary processes in order to provide the national pool of skills and talent needed for widespread implementation of concurrent engineering practices.

CONCURRENT ENGINEERING: SOME PERSPECTIVES

Objectives of Concurrent Engineering

The objectives of concurrent engineering are to 1) reduce the risk of going from weapons system design to full-scale production, 2) reduce initial weapons system acquisition costs, 3) reduce initial weapons systems operational costs, 4) improve weapons system field capability and availability, and 5) reduce the time required to go from design to deployment.

Definition of Concurrent Engineering

We define "concurrent engineering" to mean the set of methods, techniques and practices that:

- Cause significant consideration within the design phases of factors from later in the life cycle,
- Produce, along with the product design, the design of processes to be employed later in the life of the product,
- Facilitate the reduction of the time required to translate designs into the fielded products, and
- Enhance the ability of products to satisfy users' expectations and needs.

An essential element of concurrent engineering is good design engineering management which encourages the many involved engineering disciplines to support concurrently, and without delaying, the product design decision process.

Experience shows that concurrent engineering practices are most effective when they occur during initial phases of product and production process developments, and, it is already apparent from on-going industrial actions that the improvement of concurrent engineering practices will involve substantive changes and improvements in: 1) concurrent engineering-related technologies; 2) industrial structural approaches to product design and production process development; 3) the conventional-and outdated-procurement or acquisition process followed by DoD; 4) industrial capital investment; and, 5) educational emphasis on manufacturing and process engineering.

GENERAL OBSERVATIONS

- Experience since the beginning of World War II provides evidence that the best mechanism for introducing change in industry responsive to governmental demand is that of a structured, participative, contractual, cooperative arrangement with long-term co-leadership by industry and government. This has been the case not only for DoD, but for the Departments of Agriculture, Energy and Interior, and NASA.

- DoD gives a top priority to improvement in performance, capabilities, and lifetime of its weapons systems/platforms. Its recent approach to obtaining such improvement can be called "single feature improvement". These single features have become loosely referred to as the "ilities", e.g., reliability, maintainability, producibility, etc. This "single feature" or "ility" approach has unfortunately been conducive to separate, non-interacting program offices and separate budget line items in the DoD acquisition process each directed to a "single feature improvement" objective. In addition, it has led to a cumbersome, sequential, and prohibitively costly, sub-optimized procurement process.

- The use of concurrent engineering practices early in the design process will skew the traditional procurement funding profile by greater up-front loading of costs. At the same time, experience shows that potential savings in life cycle product costs from improved reliability, supportability, etc. more than offset the higher initial cost. To achieve the anticipated improvements, therefore, some well-established contractual funding and budget procedures will need to be revised and modified.

- Currently there are inhibitors in the requirements specification procedures of DoD that make it difficult and often impossible to introduce concurrent engineering practices. There are two general classes of these inhibitors: namely;

  - The lack of clarity in the definition of the requirements themselves, and

  - The lack of a realistic process for generating requirements.

- A real concern of industry is that DoD will impose on industry requirements for concurrent engineering practices that will exceed cost and schedule commitments by industry without the needed time and funding. The result will be limited, restricted, incremental improvements that do not take advantage of either the available technological or the managerial aspects of concurrent engineering practices. - Change in contract funding profiles is essential for proper deployment of these new design practices.

- Both DoD and its Defense Industrial Base are in a "catch-up" situation in developing and deploying concurrent engineering technology. To attain desired superiority DoD must become proactive in: 1) explicit R&D budget support for Concurrent Engineering; 2) explicit cooperative arrangements with and support of industry in DoD-specific manufacturing design and process development; and 3) sponsorship and support of manufacturing engineering education and training.

CONTINUING INDUSTRY SUPPORT

Important aspects of the Concurrent Engineering Program which will be considered by the Forum in the near term (through 1988), include:

1. Selection of contracts for inclusion of concurrent engineering practices

2. Financial and incentive mechanisms that can be employed to foster concurrent engineering practices

3. Means for accelerating the pace at which concurrent engineering practices and technologies are deployed

4. Contractual and specification changes, and

5. Risk reduction activities.

MAJOR FINDING

The major finding by the Forum is that Concurrent Engineering is a sound concept, that it has benefitted both the customers and the producing industries where applied, that it can and has yielded major reductions in cost and development time for modest up-front investments, and that it makes good sense to encourage the application of Concurrent Engineering practices and methodologies throughout all industrial organizations supplying the Department of Defense.

PRINCIPAL RECOMMENDATIONS

The Forum recommends that the Department of Defense:

1. Develop policies and procedures to actively encourage, but not mandate, the implementation of Concurrent Engineering practices by the Defense Industrial Base.

2. Explicitly acknowledge Concurrent Engineering as a principal means for achieving the Department's Total Quality Management (TQM) objectives.

3. Establish a "Concurrent Engineering Initiative" to provide funds for education and research to accelerate the adoption and advancement of Concurrent Engineering practices and methodologies.

4. Create a Requirements De\elopment, Request for Proposals (RFP), and Acquisition process which provides greater latitude for on-going trade-offs of system requirements. This process should:

   - Encourage sensitivity to the cost and schedule implications of pursuing marginal increases in performance

   - Place emphasis on satisfying end-user needs for which rigid specifications may be a poor surrogate.

   - Provide for elimination of RFP items consistent with USDA strategies for "Could Cost", "Streamlining", and "Accelerated Technology Insertion".

- Encourage end-user involvement with the Concurrent Engineering team, and

- Incorporate familiarization programs for government program management and acquisition personnel on the practice and implementations of Concurrent Engineering so as to facilitate credible evaluation of proposals and bids.

Specific actions through which these recommendations might be given effect are detailed in Table I, "Summary of Recommendations for Concurrent Engineering" provided as Section VI of this Report.

I. PURPOSE

This paper presents some first insights from a cross-section of industrial officials asked to consider DoD's current planning for its newly-initiated Concurrent Engineering Program. Since the implementation of the Concurrent Engineering Program will take place principally in the design and development laboratories of industry and on the production lines of industry, it is industrial managers and officials who must understand, support, and manage the Concurrent Engineering practices sought by DoD.

Similarly, it is individual industrial companies that must meet the DoD's objectives by replacing or adding equipment, by changing design and production processes, by retraining employees, by changing management practices, and presumably by changing design and production cost structures. Individual industrial managers and officers must justify the costs of these changes to senior officials and corporate boards. Again these industrial officials must understand, support, and manage the costs incurred in making the changes needed to put in place the Concurrent Engineering practices sought by DoD.

To the Defense industry official, DoD is for all intents and purposes a monopolistic customer. Although defense products/ services may be sold to foreign military customers or to other secondary domestic customers, the initial product/service is usually bid to DoD specifications or designed to DoD specifications. DoD acquisition regulations, requirements, schedules, and audits govern the defense marketplace.

It is DoD, therefore, that as the sole customer, takes the lead most frequently in introducing changes that must be implemented by the vendors as a sort of "entry fee" to the defense market. It is DoD, however, that "pays the price" for poor quality, for poor performance, for the high costs of customization and for poor reliability.

It is very obvious that in this perhaps artificial, and atypical, but still attractive market place, the need for dialog between DoD and its' defense industry is essential.

II. METHOD OF APPROACH

Meaningful interaction between industry and DoD is always difficult. This is sometimes intentional as prescribed by law, sometimes intentional as directed by DoD, and sometimes unintentional through lack of understanding and differences of purpose. Productive interaction has become even more constrained in the near past and especially now by more restrictive procurement procedures and by government concerns over fraud, corruption, and abuse. Progressive retrenchment by industry or increasing beleaguerment of industry by government, as the case may be, has become commonplace.

The needed insights by industry on how best to introduce and implement Concurrent Engineering practices were so important to OSD/USD(A) at this formative stage of the Program, that the Pymatuning Group was asked by DASD(P&L) Assistant Deputy OASD (Systems) to employ a quick-reaction mechanism that would stimulate industry response and expedite its influence on the Program. (See Attachment 1.)

The mechanism employed was that of an Industrial Concurrent Engineering Strategy Forum with voluntary participation by a selected cross-section of industry officials and managers. The membership is shown in Attachment 2. The necessary anonymity of individual viewpoints was made possible by the reporting format adopted by The Pymatuning Group. No balance or consensus was demanded: however, concerns, and opinions shared by a majority of Forum participants were assured of inclusion in this Forum report.

This initial set of insights will be augmented, refined and strengthened as the interaction continues between industry and government during the formative stages of the Concurrent Engineering Program.

III. CONTEXT

A. DoD: AN HISTORICAL PERSPECTIVE ON ITS SUPPORT OF PRODUCT AND PRODUCTION PROCESS DEVELOPMENT

World War II was a triumph of manufacturing in which the material resources of the United States were marshalled to win a war of attrition. The U. S. won by out-producing the enemy and overwhelming him with quantity of weapons and logistical support. This emphasis on production was retained by the Department of Defense as a key element of national security strategy until the mid-1950's. Then with the adoption of the "qualitative superiority" policy, manufacturing, the means of production, as a key element of weapons systems acquisition, was implicitly de-emphasized. Coincidentally, and for different reasons, this demphasis of manufacturing in the defense sector was mirrored by a similar change in attitude toward manufacturing in the civil sector.

Focus on qualitative superiority of weapon systems over quantitative (numeric) superiority has lead to focus of RDT&E on devices/features at the expense of processes. In addition, the shift to more sophisticated weapons required the development of equally sophisticated manufacturing technologies; technology which often exceeds the demands of current commercial production. Focus on qualitative superiority has also led to smaller lots or more highly differentiated, sophisticated weapons (e.g., B-2, ATF), which require innovative manufacturing processes to be developed and applied to progressively smaller production lots. Consequently, the time available to both develop and amortize new manufacturing technologies during the course of weapons production has been significantly reduced.

Historically, the DoD has relied on the strength of American manufacturing. DoD procurement has been oriented towards the purchase of items required for use by the military. It was largely assumed that the suppliers possessed the know-how and the resources required to provide the fabrication facilities in that standard processes used for commercial as well as military products were available. DoD's R&D programs financed the development and design of products needed by the military, but industry was expected to provide for the development of the wide range of technologies and the facilities that were needed to create these weapons.

For the last 20 years, in keeping with the decreased emphasis on manufacturing, both defense and civil sector research in the U. S. has focused primarily on device or product technology to the neglect of process innovation. This single-minded fixation on device technology and performance, has an impact beyond that of slowing manufacturing process innovation: it accentuates the separation between design, manufacturing, and field service. This gives rise to increased problems of producibility and supportability (these issues simply are not considered to any extent in the design phase) and increased development time. As a consequence, we have created very sophisticated weapons systems from advanced device technologies but have been increasingly frustrated by an inability to rapidly and efficiently produce these weapon systems with the reliability and maintainability required to sustain the desired operational advantage. When they are deployed, they suffer from reliability and supportability problems --all traceable to flaws in design and manufacturing.

Similarly, in the civil sector, product innovation alone has not been sufficient to capture market share. Unlike an earlier time when the U. S. could exploit the temporary monopoly arising from a novel development, markets are now increasingly dominated by those producers who can most rapidly commercialize new technologies whether or not they initially developed them. Concurrent engineering and manufacturing innovation is a key determinant in rapid commercialization.

Throughout much of this century, until the 1970's, American industry was the world-leader in all manufacturing technologies of strategic significance. As world-wide competition intensified, profit margins began to erode. In response to this competitive pressure, U. S. manufacturers sought various cost reduction means to improve their operating performance. Investments into new process development were frequently delayed or not made at all. Labor cost savings were achieved by moving manufacturing operations to low-wage areas abroad and by increasingly relying on outsourcing of components. As new products that required major investments into new processes emerged, many American companies elected to become merchandisers rather than manufacturers. For example, all VCR's are imported, and there is no American facility that is capable of mass producing the precision head-assemblies that are the heart of these recorders. This led to a significant relative weakening of the strategically significant precision electro-mechanical systems capabilities in America.

In some strategically significant industries, structural factors put American industry at a relative disadvantage with regard to making the investments into process technologies that are required to stay competitive. For example, in the semiconductor industry, new process investment requirements may reach one-third of the revenue flow for sustained periods of time, and independent American manufacturers have great difficulty competing against vertically integrated foreign firms who make their investment into components manufacturing based on expected systems sales and then also sell components which they can produce at low marginal costs. As a consequence of this, American DRAM manufacturing is virtually extinct.

Unlike the U. S., the Japanese believe that manufacturing is as important as product innovation or marketing in obtaining market share and have increasingly emphasized manufacturing design and process research and development. While it is very difficult to provide precise figures, different studies are in general agreement that Japan spends a much larger fraction of its R&D funds on manufacturing than does the U. S. One study puts the percentage of R&D devoted to manufacturing at 40 percent in Japan versus 10 percent in the U. S. Another study estimates that Japan devotes two-thirds of its R&D funds to improved processes and one-third to improved products, while it estimates that in the U. S. this ratio is exactly reversed. In design, the Japanese have pioneered in the development and use of concurrent engineering or simultaneous engineering as a way of identifying and addressing producibility and supportability concerns early in design--an approach essentially unknown in the Defense Industrial Base. This focus on manufacturing process technology and concurrent engineering together with continuous capital investment in new process technology has paid big dividends. The average development time, concept to first production, for a variety of Japanese products--from aerospace to office automation equipment--is typically one-half that for comparable U. S. products.

This focus has lead to a distinctive competitive advantage to Japanese manufacturers, and the ascension to a position of dominance by foreign manufacturing over domestic industries in key areas. A prime example is Honda Motors decision to move to a 3-year new auto entry cycle from the U. S. industry average of nearly 7 years. This capacity to apply and implement manufacturing innovation has resulted in both low product cost and high quality.

Industry managers believe that the Defense Industrial Base could produce just as efficiently if modern structural factor changes and manufacturing innovation were emphasized by its primary customer, DoD, rather than the current emphasis on crippling documentation and on prohibitions to process innovation. If the Defense Industrial Base were allowed to operate effectively the DoD could have all the systems it requires early enough to allow its technical superiority to convey decisive operational advantage, with high reliability so they work when needed, and with corresponding improvement in the "tooth-to-tail" ratio. All this could be accomplished in the face of a flat to declining defense budget. The manufacturing process is an important element in a broader strategy to improve defense acquisition.

Limited examples of concurrent product and process development can be found in current DoD practice. One example is the development of precision optics fabrication capabilities in parallel with laser based SDI systems, where it has been recognized that, assuming adequate performance of the system, implementation would be impossible without concurrent advances in manufacturing. Another example is the DoD VHSIC program. The VHSIC program has put into effect a structured methodology for designing and manufacturing very high performance and density integrated circuits. Throughout the effort, significant attention has been given to concurrent engineering practices which have focused on producibility, interoperability, reliability, maintainability, and testability. A key element of the program has been the rapid prototyping and simulation activity supporting the design and manufacturing cycle. The elements of concurrent engineering are imbedded in all VHSIC chips which are used in weapon systems.

The broad application of concurrent engineering demands much more advanced manufacturing technology capabilities than did the sequential design approach. American industry is currently less advanced in these technologies than is its foreign competition and a major national effort is required to address this shortcoming. While the U.S. has not lost its scientific leadership or capacity to generate new technologies, there is concern that the lack of emphasis on engineering education, and more specifically, manufacturing education, weakens the national commitment to use technology to improve the productivity of industry, and diminishes its performance in international competition.

A specific difficulty is the formal higher education of manufacturing engineers. A recent study indicates that in the U.S. today there are only two degree-granting programs in manufacturing engineering; at Boston University (30 graduates in 1986-87) and at Utah State University (12 graduates in 1986-87). The U.S. produced only 42 manufacturing degree graduates out of 75,735 total engineering graduates! Further, out of some 1.4 million practicing engineers in the U.S., only about 75,000 are practicing as manufacturing engineers--and of these only 3,000 hold engineering degrees.

Engineering education which accentuates differences among engineering disciplines is antithetical to the spirit of concurrent engineering. The current educational emphasis on specialized disciplines needs to change to an emphasis on integrated interdisciplinary processes for creating, delivering, maintaining, and disposing of new products so as to provide the national pool of skills and talent required to implement the practice of Concurrent Engineering.

B. CONCURRENT ENGINEERING: SOME PERSPECTIVES

Objectives of Concurrent Engineering

The objectives of concurrent engineering are to 1) reduce the risk of going from weapons system design to full-scale production, 2) reduce initial weapons system acquisition costs, 3) reduce initial weapons system operational costs, 4) improve weapons system field capability and availability, 5) reduce the time required to go from design to deployment.

Definition of Concurrent Engineering

We define "concurrent engineering" to mean the set of methods, techniques, and practices that:

- cause significant consideration within the design phases of factors from later in the life cycle,

- produce, along with the product design, the design of processes to be employed later in the life of the product,

- facilitate the reduction of the time required to translate designs into fielded products, and

- enhance the ability of products to satisfy users' expectations and needs.

Concurrent engineering is an essential element of good design engineering management which encourages the many involved engineering disciplines to support concurrently, and without delaying, the product design decision process.

Concurrent engineering practices occur during initial phases of product and production process developments. Concurrent engineering practices repeat as many times during a procurement process as do iterations in product and process design developments.

The only effective way to reduce the life cycle cost of a weapons system is to ensure that it is designed from the beginning with as much attention to operational costs (and operational readiness) as is given to weapons system function. The biggest cost driver for initial procurement costs is change once production begins. Change can double the cost of sub-contracted items. The goal of concurrent design is to "do it right the first time", so that changes will not be required.

Although concurrent engineering is a long-accepted engineering practice, the recent rapid advances which are without precedent in electronic, computer, information and automation technologies among others, have made obsolete overnight the concurrent engineering practices of a decade ago. Simultaneously, these same technologies make possible an unparalleled improvement in product/system performance, reliability, and maintainability throughout the product or system life cycle.

One aspect which adds greatly to the complexity of modern weapons system development, is that the contractor teams comprise many individual companies, of varying sizes and locations, and that the definition of the product and the processes used to build it and maintain it are performed in a number of widely-distributed locations.

Concurrent Engineering requires larger numbers of disciplines to work much more closely and interactively together, to achieve the stated objectives. Larger numbers of companies participating in future weapons system development will exacerbate the already growing communications and data sharing problems. In every weapons system procurement, the cost of contractually-required product and program documentation is large and growing, however, very large potential savings are anticipated through development and implementation of electronic means of data delivery.

Concurrent engineering practices are an integral part of quality management and quality engineering. Hence the DoD Concurrent Engineering Program is an integral part of and a key foundation for DoD's Total Quality Management Program. Through the use of concurrent engineering practices the focus of quality improvements can be moved to the beginning of product development and the associated production process developments. This will reduce the very expensive resolution of quality and performance problems first observed in later procurement phases. It will also represent, through concurrency of design, the necessary first stage of both product and process design optimization.

The improvement of concurrent engineering practices will involve substantive changes and improvements in:

1. Concurrent engineering-related technologies

2. Industrial structural approaches to product design and production process development

3. The conventional-and outdated-procurement or acquisition process followed by DoD, and

4. Industrial capital investment, and

5. Educational emphasis on manufacturing and process engineering.

C. FACTORS INFLUENCING INDUSTRY'S ACCEPTANCE OF DOD OBJECTIVES

Since OSD management is just in the process of delineating DoD objectives for the Concurrent Engineering Program, one should anticipate that there will be considerable fluidity in these objectives for some time to come.

At the same time, industry recognizes that DoD objectives for such a program generally impose requirements and goals on its contractor base as well as on DoD agencies, departments, and services. The requirements and goals that can be imposed on industry by DoD are properly constrained by legislation, regulation, and Executive Branch directives. Pragmatically, however, there is still considerable flexibility in what can be requested from the defense industry by DoD.

The extent of requirements that can realistically be levied upon and implemented by industry are generally determined by some combination of factors such as:

- The perceived benefit to the company's overall Balance Sheet (for both defense and consumer business) as forecasted in the company's Financial Plan,

- The resultant attractiveness to the company of defense business in the near-term as well as in the long-term,

- The arrangements for sharing of front-end and down-side risks between DoD and the company,
- The pace of change demanded by DoD and whether it can match the corporate planning cycle or whether it is disruptive or arbitrary in the sense of schedule, cost and skill-mix,
- The effect on the company's competitiveness for DoD contracts,
- The likelihood of significant reductions in certain sectors of the Industrial Supplier Base,
- The perceived effect on the complexity of the DoD procurement and acquisition processes,
- The funding or financial risk-sharing mechanisms that are being identified and/or proffered by DoD,
- The loss of company control over "proprietary" data, marketable products and production processes
- The potential for micromanagement by DoD and
- The public perception.

The observations and recommendations of this report reflect industry's concern with and sensitivity to these factors.

IV. GENERAL OBSERVATIONS BY INDUSTRY

This initial set of insights concentrates on those issues and actions that will be useful during the formative stage of the Concurrent Engineering Program of DoD.

The first comment is a plea to DoD to identify those aspects of the modified start-up phases of the acquisition and contractual processes that will necessitate changes by industry in process technology deployment, in structural factors, in front-end scheduling, in capitalization, in product development and production schedules, and in funding profiles.

The underlying reason is that introducing change in industry is more than just a demand for new product development. It implies changes as noted earlier in manufacturing processes, financial changes and changes in corporate structures. And, the deployment of Concurrent Engineering practices by industry is just such a process change.

Experience since the beginning of World War II provides evidence that the best mechanism for introducing change in industry responsive to governmental demand is that of a structured, participative, contractual cooperative arrangement with long-term co-leadership by industry and government. This has been the case not only for DoD, but for the Departments of Agriculture, Energy and Interior, and NASA.

Product development in the United States has been a largely sequential process. Engineers handle the design and "toss it over the wall" to manufacturing specialists. The manufacturing department then devises means to produce and deliver the product: finally field service engineers maintain the equipment and resolve customer complaints.

Sequential product development can still work reasonably well with unsophisticated products, and where the designer has broad knowledge of manufacturing and use of the product. However, if the product is a highly sophisticated weapons system pushing the state-of-the-art, sequential development will generally yield designs which are needlessly difficult (and expensive) to manufacture, are prone to failure, and difficult to maintain in the field.

DoD gives a top priority to improvement in performance, capabilities, and lifetime of its weapons systems/platforms. Its recent approach to obtaining such improvement is characterized by what can be called "single feature improvement". These single features have become loosely referred to as the "ilities", e.g., reliab<u>ility</u>, maintainab<u>ility</u>, producib<u>ility</u>, etc. This "single feature" or "ility" approach has unfortunately been conducive to separate, non-interacting program offices and separate budget line items in the DoD acquisition process each directed to a "single feature improvement" objective. In addition, it has led to a cumbersome, sequential, and prohibitively costly, sub-optimized procurement process.

Concurrent engineering practices provide real promise for escaping from the out-dated "ility-silo" syndrome. A specially applicable feature of concurrent engineering is the multifunction design team which, equipped with appropriate tools, e.g., CAD/CAM, insures up-front consideration of most if not all the "ilities" or single-feature improvements.

Currently there are inhibitors in the requirements specification procedures of DoD that make it difficult and often impossible to introduce concurrent engineering practices. There are two general classes of these offending inhibitors: namely;

- The lack of clarity in the definition of the requirements themselves, and

- The lack of a realistic process for generating requirements.

The first class of inhibitors occurs because of DoD's over-specified acquisition process which, in reality, results in an inability currently to define real requirements in the early concept and design definition phases of a program. DoD is, therefore, unable to realize the benefits of concurrent engineering practices in later system phases of production, operation, and maintenance. Often, early phases of major programs have different objectives set by Program Managers which do not factor in full life cycle considerations. This results from setting initial unrealistic requirements, perhaps motivated by performance without giving adequate priority to producibility, cost, or life cycle support.

The perceived immutability of requirements, and the isolation of customer from vendor caused by the Defense acquisition process, pose special problems for the application of concurrent engineering in Defense acquisition. Performing adequate trade-off studies during early phases for a given DoD system is essential to determine the recommended development implementation. Support tools are needed so that these trade-offs can be performed with reasonable prioritization applied.

The second class of inhibitors relates to the DoD process of generating the requirements. In the industry sector, a strong system engineering function which directs all areas including technical product definition, schedules for development, and all aspects of cost, is essential for a successful product offering. Similarly, DoD must also have a strong system engineering function which directs all phases of the DoD system development, production, and support activities. Frequently, this function is lacking or is delegated to a level which does not provide adequate direction. The result of not having strong system engineering leadership in the government on a specific weapon system is catastrophic to realizing concurrent engineering attributes. Inadequate trade-offs and prototyping leading to incorrect conclusions during Concept Definition phases will often establish unrealistic and inadequate objectives for Full Scale Development and Production.

A related problem is that of over-specification of the weapons system leading to unnecessary design objectives which add cost and risk to the program. A strong system engineering function in this case would apply reasonable judgment to the imposed specification tree and eliminate unnecessary requirements.

The current DoD acquisition process of technical leveling of all competition is often an inhibitor to innovative concurrent engineering approaches because specification and contract language required for leveling is frozen too early in the process and alternate approaches are discouraged.

The use of concurrent engineering practices early in the design process will skew the traditional procurement funding profile by greater up-front loading of costs. Experience shows, however, that potential savings in life cycle product costs from improved reliability, supportability, etc. more than offset the higher initial cost.

DoD contractors generally strongly endorse the Concurrent Engineering Program of DoD. However, they share a major concern that requests by DoD for concurrent engineering practices that exceed contractor's cost and schedule commitments will be imposed without the necessary attendant time and funding to design, develop, and test a responsive configuration. The result will be limited, restricted, incremental improvements that do not take full advantage of either the available technological or managerial aspects of concurrent engineering practices. They also share common concerns about any meaningful wide-spread introduction of concurrent engineering practices in the current regulatory environment now coupled with on-going contractor investigations. Nevertheless, the consensus on the urgency for improving weapons systems/platforms design and development processes far exceeds these concerns.

Both DoD and its Defense Industrial Base are in a "catch-up" situation in developing and deploying concurrent engineering technology. As noted in Section III, DoD has consistently neglected process innovation since World War II even in those specialized types of production peculiar to DoD's military needs.

For DoD to reach its quantitive superiority over foreign adversaries and to achieve an acceptable deployment schedule for its weapons systems/platforms it must immediately become proactive in three areas of Concurrent Engineering activities: namely;

1. Explicit R&D budget support for Concurrent Engineering

2. Explicit cooperative arrangements with and support of industry in DoD-specific manufacturing design and process development, and

3. Sponsorship and support of manufacturing engineering education and training.

V. CONTINUING INDUSTRY SUPPORT

The current members of the Industrial Concurrent Engineering Strategy Forum believe that their insights are valuable to the DoD, especially at this formative stage of the Concurrent Engineering Program. They also are convinced from experience that their review of and comments on the evolving DoD and Service programs will serve to assure a realistic Program that can be supported by the Defense Industry.

The Pymatuning Group plans to continue the present Forum effort to more fully develop important aspects of the Concurrent Engineering Program that need attention in the near term (through 1988). These include:

1. Selection of contracts for inclusion of concurrent engineering practices,

2. Financial and incentive mechanisms that can be employed to foster concurrent engineering practices,

3. Means for accelerating the pace at which concurrent engineering practices and technologies are employed,

4. Contractual and specification changes, and

5. Risk reduction activities.

TABLE I

VI. SUMMARY OF RECOMMENDATIONS FOR CONCURRENT ENGINEERING

1. DEVELOP POLICIES AND PROCEDURES TO ACTIVELY ENCOURAGE, BUT NOT MANDATE, THE IMPLEMENTATION OF CONCURRENT ENGINEERING PRACTICES BY THE DEFENSE INDUSTRIAL BASE.

   a. Continue the informal, participative relationship between industry and DoD to constructively accelerate the deployment of Concurrent Engineering.

   b. Establish a strong systems engineering function for major DoD programs to ensure that Concurrent Engineering practices are incorporated in weapon systems development.

   c. Re-examine, for compatibility with Concurrent Engineering concepts, the approach DoD currently uses for generating requirements and specifications so as to recognize commerciality both in terms of system requirements and life cycle management processes.

   d. Re-evaluate DoD competition policies for compatibility with Concurrent Engineering practices. Consider permitting industry consortia to set forth the best set of proposals to satisfy true requirements, without regard to limitations forced by competition advocacy. Long term stable relationships between primes and vendors should be facilitated.

   e. Make a concerted effort to structure production contracts to allow contractor-DoD sharing of the life-cycle savings resulting from the application of Concurrent Engineering.

2. EXPLICITLY ACKNOWLEDGE CONCURRENT ENGINEERING AS A PRINCIPAL MEANS FOR ACHIEVING THE DEPARTMENT'S TOTAL QUALITY MANAGEMENT (TQM) OBJECTIVES.

   a. Incorporate Concurrent Engineering objectives into the Under Secretary of Defense for Acquisition (USD(A)) strategies under the aegis of "Could Cost", i.e., each acquisition to be aggressively examined by a contractor to report back what a program could cost if design requirements and management systems which do not add value to the product are eliminated.

b. Incorporate Concurrent Engineering objectives into USD(A) strategies on the matter of Acquisition Regulatory Reform to enable commanders and managers to get the quality products and services they want, when they want them at a reasonable price.

c. Include Concurrent Engineering practices in USD(A) strategies as a key means for reducing the lead time for Technology Insertion into weapon systems and platforms.

d. Incorporate Concurrent Engineering practices into USD(A) strategies as integral to the knowledge base of the corps of dedicated and qualified Acquisition Officers.

e. Incorporate Concurrent Engineering practices into DoD Directive 5000.43 which deals with Streamlining and Elimination of Counterproductive Requirements, and provide flexibility to subsequently change specifications to facilitate employment of Concurrent Engineering practices.

3. ESTABLISH A "CONCURRENT ENGINEERING INITIATIVE" TO PROVIDE FUNDS FOR EDUCATION AND RESEARCH TO ACCELERATE THE ADOPTION AND ADVANCEMENT OF CONCURRENT ENGINEERING PRACTICES AND METHODOLOGIES AND TO PUT A FOCUS ON THESE RECOMMENDATIONS.

a. Initiate immediately a broad program of education of both government and industrial personnel to develop receptivity to the contractual and procurement changes which must accompany the adoption of Concurrent Engineering practices.

- Incorporate Concurrent Engineering strategy briefings and lectures into appropriate DoD educational curricula and structures.

- Promote, in cooperation with relevant industry associations, an "Education of Industry" program to present the Concurrent Engineering philosophy to senior and middle management levels of Defense Base Industries.

b. Initiate Concurrent Engineering Pilot Programs within DoD as a means for familiarization and training of DoD personnel.

c. Consider re-establishing a program along the lines of the National Defense Education Act of 1958 to encourage the higher education of manufacturing engineers for the Defense Industrial Base.

d. Establish an explicit design and manufacturing research budget line at a level which is a significant percentage of the amount allocated for device research and weapon system development, and conduct design and manufacturing research in the following areas:

- Concurrent Engineering methods and techniques focusing on means for identifying tradeoffs across performance, cost, manufacturability and supportability,

- Product design methods keyed to low volume production,

- New techniques for analyzing and improving product designs for enhanced quality and supportability, and

- Systematic design procedures that identify quality factors and focus on quality-by-design rather than quality-by-oversight.

e. Use the R&D Program to highlight demonstrations centered on existing weapon systems programs which can focus the R&D, establish quantitative goals, and serve as technology transfer mechanisms.

f. Provide for each procurement request for sophisticated, novel or complex products to include a parallel funding line for manufacturing innovations.

g. Identify and apply funding mechanisms and incentives that can be used for Concurrent Engineering developments. In particular, IRAD and CRAD funding for Concurrent Engineering projects should be encouraged.

4. CREATE A REQUIREMENTS DEVELOPMENT, REQUEST FOR PROPOSALS (RFP), AND ACQUISITION PROCESS WHICH PROVIDES GREATER LATITUDE FOR ON-GOING TRADE-OFFS OF SYSTEM REQUIREMENTS. THIS PROCESS SHOULD:

- ENCOURAGE SENSITIVITY TO THE COST AND SCHEDULE IMPLICATIONS OF PURSUING MARGINAL INCREASES IN PERFORMANCE.

- PLACE EMPHASIS ON SATISFYING END-USER NEEDS FOR WHICH RIGID SPECIFICATIONS MAY BE A POOR SURROGATE.

- PROVIDE FOR ELIMINATION OF RFP ITEMS CONSISTENT WITH USD/A STRATEGIES FOR "COULD COST", STREAMLINING", AND "ACCELERATED TECHNOLOGY INSERTION",

- ENCOURAGE END-USER INVOLVEMENT WITH THE CONCURRENT ENGINEERING TEAM, AND

- INCORPORATE FAMILIARIZATION PROGRAMS FOR GOVERNMENT PROGRAM MANAGEMENT AND ACQUISITION PERSONNEL ON THE PRACTICE AND IMPLICATIONS OF CONCURRENT ENGINEERING SO AS TO FACILITATE CREDIBLE EVALUATION OF PROPOSALS AND BIDS.

a. Establish, in both Government and Industry, program engineers specifically responsible to achieve better balance between improved product life-cycle features and product performance.

b. Clarify MIL-STD-499 on Engineering Management to place the responsibility for all "ilities" (reliability, maintainability, supportability, producibility, etc.) with the Program Engineer.

c. Ensure that RFPs endorse and use the Program Engineer concept and that Source Selection Boards are not influenced by the "ilities" as if each had equal merit for the particular application.

d. Include in the proposal evaluation process an assessment of the design and manufacturing process capabilities. The quality of the design and manufacturing process should be made an integral part of the selection considerations, and should be an explicit condition for award of contracts.

MAY 3 1988

THE OFFICE OF THE ASSISTANT SECRETARY OF DEFENSE
WASHINGTON, D.C. 20301-8000

26 April 1988

PRODUCTION AND
LOGISTICS

Dr. Ruth M. Davis, President
The Pymatuning Group, Inc.
2000 N. 15th Street, Suite 707
Arlington, VA 22201

Dear Dr. Davis,

As you know, the UnderSecretary of Defense (Acquisition and Logistics) has recently stated his intent to initiate a Concurrent Design program as a high-priority defense effort. I have attached his memorandum to that effect for you information.

Industry plays a key role in developing and implementing the policies, procedures, and practices that will characterize concurrent design as a required step in the modernized manufacturing processes necessary for future weapons systems procurements. It is essential therefore that OSD officials have an effective means for continuing and timely dialogue with industrial representatives responsible for, knowledgeable of, concurrent design as just discussed.

I should like you to arrange and take responsibility for effecting such a continuing dialogue between selected and voluntary industry representatives and our office. I anticipate that this can be accomplished in manner similar to the CALS Senior Strategy Forum which you manage.

As we have discussed, Mr. Larry Lemke of McDonnell Douglas would be a most acceptable industry chairman for this activity. Contractual funding to support this effort has been provided to The Pymatuning Group, Inc.

Sincerely,

Russell K. Shorey

Russell Shorey

Attachment 2

INDUSTRY PARTICIPANTS IN DOD INDUSTRIAL

CONCURRENT ENGINEERING STRATEGY FORUM

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Attachment 3

FINANCIAL DIALOGUE

BETWEEN

GOVERNMENT AND INDUSTRY

N. B.

Figures VI.5 and VI.6 are not included in this Attachment

April, 1988

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VI. INVOKING FINANCIAL DIALOGUES FOR COOPERATIVE ALLIANCES

The spectrum of activities on which this paper has concentrated starts with basic research and invention. From that beginning stage, the action moves into development and testing, followed by innovation into product development, then transitions via manufacturing technology and manufacturing processes through the production cycle, and finally enters the marketplace where operational testing and acceptance occurs after acquisition by consumers and users.

This spectrum subsumes a number of highly interactive processes and entities all of which have, in the past, generally been treated as independent of one another with each having its own separate governing bodies of law, regulation, and financial mechanisms. Familiar instances of these entities would include:

1. The research and development cycle
2. The manufacturing process
3. The domestic marketplace, and the foreign marketplace
4. The public sector, and the private sector
5. The production industry
6. The financial industry
7. Public regulation
8. Government financing
9. University research
10. Export and import policies
11. Small vs large business

Cooperation has more often been discouraged than encouraged by law and by tradition. Mismatches frequently exist between allowable financial support mechanisms and required financial needs. Dialogues,

- Our old and our new manufacturing processes, which in turn help explain our comparative competitive position in the world market,

- The vigor of our national technological strength and leadership,

- The structure and responsiveness of our defense industrial base,

- The set of available and popular financial mechanisms for supporting our domestic technology innovation and manufacturing base; this serves as the current best indicator of the roles ascribed to government in government-industry interactions, and

- The potential utility of the many currently proposed cooperative arrangements among industrial enterprises and between industry and government.

Two of the more obvious observations to be drawn from the portrayal of what can be labelled the Product-Innovation Manufacturing Financial Support Spectrum are as follows:

- No single financial mechanism is useful in an across-the-board manner for the entire product innovation or manufacturing life cycle, nor, is a single financial mechanism useful across larg segments of either spectrum; and

- Financial mechanisms must be custom-fitted to match the life cycle phases in which the probler in question is occurring.

Figure VI.5 illustrates these observations through depiction of some well-documented applications of specific funding mechanisms.

The matrix of activity depicted in Figure VI.6 is intended to provide the reader with the means of assessing those direct and indirect instruments of financial assistance available for stimulating technological innovation. In addition, the matrix some institutional obstacles that appear inherent to those circumstances surrounding the establishment of the consortia. Effective incentives to overcome both types of obstacles might include:

- Tax credits,
- Accelerated depreciation, and
- Price guarantees.

On the other hand, large capital exposure to such a consortium effort, (and to any typical company's size as a member) plus the traditional uncertainties associated with regulations might suggest incentives such as:

- Tariffs,
- Loan guarantees, and
- Regulatory relief through the removal of procedural inconsistencies.

The creation of a "level playing field" made up of the appropriate combination of support mechanisms requires infinite patience and imagination on behalf of the initiator.

A number of important policy issues will surface for consideration whenever a financial dialogue is proposed regarding prospective government-industry cooperative efforts. Several of the key issues involved have already been described in earlier portions of this paper. As noted, it is clear that government-industry cooperative policy options rarely can be expected to take identical form in every instance, nor is it probable that their results will be optimized on every occasion. In sum, therefore, difficult choices will have to be made. Some of the major ramifications of such choices are illustrated in Figure VI.6, and have been narrowed down to those expected to accomplish one or all of the following:

- Provision of most economic efficiency
- Provision of greatest breadth of participation

FIGURE VI.1 - THE PRODUCT INNOVATION SPECTRUM OF ACTIVITIES

1. Basic Research and/or Invention

   ...Proof of Concept

   ...Theory

   ...Physical Limits

2. Applied Research and Development

   ...Component or Device-oriented

   ...NOT Product Specific

3. Product or System Design (Generic)

4. Prototype Development and Testing

5. Customized (Proprietary) Product Design Development, Test and Engineering

6. Product/System Production

7. Product/System Documentation

   ...Operational

   ...Maintenance, etc.

8. Marketplace Activities

   ...Promotion

   ...Sales

   ...

9. Product/System Maintenance

FIGURE VI.3 - FINANCIAL SUPPORT MECHANISMS

A. Direct Financial Instruments

1. Contracts
2. Payments
3. Endowments
4. Loans
5. Grants -- Research
   Construction

B. Indirect Financial Assistance

1. Guaranteed Loans
2. Facility and Equipment Leasing (Govt. owned)
3. Patent Ownership and Licensing Rights
4. Trademark Rights and Copyrights
5. Government Furnished Equipment and Facilities, e.g., GO-COs (Government-owned, Company-operated)
6. Technology Transfer
7. Personnel Exchange/Liaison
8. Export Subsidies
9. Import Tariffs
10. Guaranteed Pricing...Price Floors...
11. Voluntary Restraint Agreement (VRA) on Imports

    ...Sec. 232, Trade Act

FIGURE VI.3 - Financial Support Mechanisms (continued)

E. Non-economic Incentives, i.e., Constraint Removal

Regulatory Relief/Reform

...Removal of procedural inconsistencies

...Reduce conflicts over standards

...Eliminate data duplication

...Minimize impact of future changes

FIGURE VI.4 - THE PRODUCT INNOVATION-MANUFACTURING-FINANCIAL SUPPORT SPECTRUM
(Continued)

C. The Financial Support Spectrum

C.1: For Product Innovation

Research Contracts /Grants	Endowments	Technology Transfer	Patents Licenses Trademarks Copyrights	Cooperative R&D Ventures	IR&D	Tax Credits for R&D (Incl. tax Write-offs)	Capital Investments Aids	Facilities Construction and/or Lease	Payments	Personnel Exchange, Liaison

C.2: For the Manufacturing Process

Purchase; Pricing; and Completion Loan Guarantees: Loans	Contracts Grants - Research and Construction	Facilities and Equipment Leasing and GOCOs	Cost-sharing	Coopera-tive Production Ventures	Export Subsidies	Coopera-tive Manu-facturing Ventures	Tax Credits, Write-offs, Capital Investment Aids	Patents Licenses Trademarks Copyrights	Regulatory Relief and/or Reforms	Payments